MULTIMEDIA UNIVERSITY

STUDENT ID NO

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# MULTIMEDIA UNIVERSITY

# FINAL EXAMINATION

**TRIMESTER 2, 2018/2019**

## DET5038 – POWER ELECTRONICS

(Diploma in Electronic Engineering)

6 MARCH 2019
2:30 pm – 4:30 pm
(2 Hours)

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**INSTRUCTIONS TO STUDENT**

1. This question paper consists of **6** pages excluding cover page.
2. Answer **ALL** questions. All necessary working steps must be shown.
3. Write all your answers in the answer booklet provided.

## QUESTION 1 [20 marks]

(a) Explain the differences between power diode and SCR. (4 marks)

(b) Sketch the *V-I* characteristic of SCR clearly indicating the holding current, maximum reverse voltage and forward bias on-state current. (6 marks)

(c) Draw the circuit diagram of a single phase half wave uncontrolled rectifier operating from a 230 V, 50 Hz supply, with purely resistive load of 20 Ω. Sketch the waveforms of its source voltage, output voltage, output current and source current. (10 marks)

## QUESTION 2 [20 marks]

(a) Draw the circuit diagram of a Boost DC-DC Converter and explain how its output voltage can be controlled. Also, explain the effect of duty cycle and switching frequency on the ripple voltage of the output voltage. (10 marks)

(b) Draw the circuit diagram of a single phase PWM full-bridge DC-AC inverter and explain its operation. Sketch its output voltage and current waveforms for a duty cycle of 0.5 for a purely resistive load. (10 marks)

**Continued ...**

## QUESTION 3 [20 marks]

(a) A power MOSFET is used as a switch to supply power to a purely inductive load, as shown in Figure 1. Assume that the switch is in the on-state and off-state for the same time duration at a switching frequency of 100 kHz. Using the data given, determine the total power loss in the MOSFET. (17 marks)

Drain-source on state resistance, $R_{DS\text{-}on} = 0.05\ \Omega$
Reverse leakage current, $I_{DSS} = 200\ \mu A$
DC power supply, $V_{DD} = 200$ V
Turn on time, $\tau_{on} = 50$ ns;
Turn off time, $\tau_{off} = 200$ ns
On state current, $I_{DS\text{-}on} = 20$

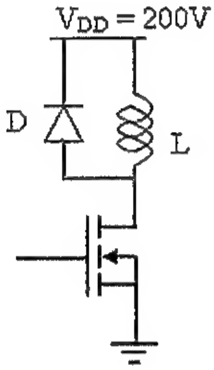


Figure 1

(b) Determine the total power loss if the load is purely resistive. (3 marks)

**Continued ...**

**QUESTION 4 [20 marks]**

(a) A single phase full wave diode-bridge rectifier operating from a 230 V, 50 Hz main, supplies power to a purely inductive load, represented by a constant current of 20 A. Find the

- (i) average output voltage (2 marks)
- (ii) average output current (2 marks)
- (iii) RMS output voltage (2 marks)
- (iv) ripple voltage (2 marks)
- (v) ripple voltage factor. (2 marks)

(b) A DC-DC Buck-Boost converter is operating from a 10 V DC voltage source. It supplies 45 W power to a 5 Ω load resistor under continuous conduction mode at a switching frequency of 10 kHz. Assume that the filter capacitance is 220 μF and the diode is ideal. Determine the

- (i) output voltage and duty ratio (4 marks)
- (ii) minimum inductance value needed for this converter for continuous conduction mode of operation (3 marks)
- (iii) percentage ripple in the output voltage. (3 marks)

**Continued ...**

## QUESTION 5 [20 marks]

(a) A single phase half-bridge inverter with a DC input voltage ($V_P$) of 100 V is required to produce an AC square wave output voltage at 50 Hz across a resistive load of 100 Ω.

| | | |
|---|---|---|
| (i) | Draw the circuit diagram and label the components | (3 marks) |
| (ii) | Calculate the RMS value of the output voltage, $V_{0,\,RMS}$ | (2 marks) |
| (iii) | Calculate the power output | (2 marks) |
| (iv) | Calculate the total harmonic distortion in the output voltage | (3 marks) |

*Hint:* $V_{1,\,RMS} = 0.9\ V_P$

(b) A half-bridge resonant inverter with unidirectional switch is as shown in Figure 2. The capacitor voltage at time $t = 0$ s is given as 120 V. Determine the following:

| | | |
|---|---|---|
| (i) | Damping factor, $\alpha$. | (2 marks) |
| (ii) | Angular resonant frequency, $\omega_o$ | (2 marks) |
| (iii) | Angular ringing frequency, $\omega_r$ | (3 marks) |
| (iv) | The expression for the instantaneous load current, $i(t)$. | (3 marks) |

*Hint:* $i\ (t) = \dfrac{V_s + V_{C0}}{L\omega_r} e^{-\alpha t} \sin \omega_r t$

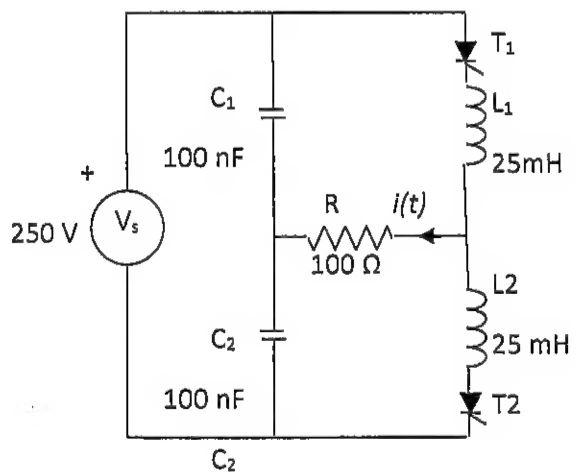


Figure 2

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# APPENDIX

Table 1 Switching power loss of power BJT

| | Resistive Load | Inductive Load |
|---|---|---|
| ON state | $P_{on}=[V_{CE(sat)}I_{C(on)}+V_{BE(on)}I_{B(on)}]\frac{t_{on}}{T}$ | $P_{on}=[V_{CE(sat)}I_{C(on)}+V_{BE(on)}I_{B(on)}]\frac{t_{on}}{T}$ |
| OFF state | $P_{off}=[V_{CC}I_{C(leak)}]\frac{t_{off}}{T}$ | $P_{off}=[V_{CC}I_{C(leak)}]\frac{t_{off}}{T}$ |
| Turn On | $P_{turn-on}=V_{CC}I_{C(on)}\frac{\tau_{on}}{6T}$ | $P_{turn-on}=V_{CC}I_{C(on)}\frac{\tau_{on}}{2T}$ |
| Turn Off | $P_{turn-off}=V_{CC}I_{C(on)}\frac{\tau_{off}}{6T}$ | $P_{turn-off}=V_{CC}I_{C(on)}\frac{\tau_{off}}{2T}$ |

Table 2 Switching power loss of power MOSFET

| | Resistive Load | Inductive Load |
|---|---|---|
| ON state | $P_{on}=I^2_{D(on)}R_{DS(on)}\frac{t_{on}}{T}$ | $P_{on}=I^2_{D(on)}R_{DS(on)}\frac{t_{on}}{T}$ |
| OFF state | $P_{off}=I_{D(off)}.V_{DD}\frac{t_{off}}{T}$ | $P_{off}=I_{D(off)}.V_{DD}\frac{t_{off}}{T}$ |
| Turn On | $P_{turn-on}=\frac{V_{DD}I_{D(on)}\tau_{on}}{6T}$ | $P_{turn-on}=\frac{V_{DD}I_{D(on)}\tau_{on}}{2T}$ |
| Turn Off | $P_{turn-off}=\frac{V_{DD}I_{D(on)}\tau_{off}}{6T}$ | $P_{turn-off}=\frac{V_{DD}I_{D(on)}\tau_{off}}{2T}$ |

Half wave rectifier: $V_{0avg}=V_m/\pi$ ; $V_{0rms}=V_m/2$ where $V_m= 1.414\ V_{Srms}$

Full wave rectifier: $V_{0avg}=2V_m/\pi$ ; $V_{0rms}=V_m/1.414$

Table 3 Useful equations of DC to DC converters

| Buck Converter | Boost Converter | Buck-Boost Converter |
|---|---|---|
| $V_o = DV_s$ | $D = 1 - \frac{V_s}{V_o}$ | $D = \frac{V_O}{V_s + V_O}$ |
| $I_L = \frac{V_o}{R}$ <br> $(\Delta i_L)_{close} = \frac{V_s - V_o}{L} DT$ <br> $(\Delta i_L)_{open} = -\frac{V_o}{L}(1-D)T$ | $I_L = \frac{V_s}{R(1-D)^2}$ <br> $(\Delta i_L)_{close} = \frac{V_s}{L} DT$ <br> $(\Delta i_L)_{open} = \frac{V_S - V_o}{L}(1-D)T$ | $I_L = \frac{V_s D}{R(1-D)^2}$ <br> $(\Delta i_L)_{close} = \frac{V_S}{L} DT$ <br> $(\Delta i_L)_{open} = -\frac{V_o}{L}(1-D)T$ |
| $L = \frac{(1-D)R}{2f}$ | $L = \frac{D(1-D)^2 R}{2f}$ | $L = \frac{(1-D)^2 R}{2f}$ |
| $C_{min} = \frac{1-D}{8Lf^2 \frac{\Delta V_o}{V_o}}$ | $C = \frac{D}{Rf \frac{\Delta V_o}{V_o}}$ | $C = \frac{D}{Rf \frac{\Delta V_o}{V_o}}$ |